Flexibility-based Anti-islanding Protection of a Microgrid Integrated with Power Grid

Ahmed M. A. Haidar, Al-Khalid bin Hj Othman
Department of Electrical and Electronic Engineering
Universiti Malaysia Sarawak
Kota Samarahan, Malaysia
ahahmed@unimas.my

Luiz A. C. Lopes
Electrical and Computer Engineering Department
Concordia University
Montreal, Quebec, Canada
lalopes@ece.concordia.ca

***Abstract*— The widespread adoption of Renewable Energy Resources (RER) and Plug-in Electric Vehicles (PEVs) in distribution systems has achieved a substantial energy share, allowing the microgrid to participate in the open market. In fact, the high penetrations of RER and PEVs have increased the importance of impact assessment involving system protection. A framework is presented in this paper for modeling the combined operations of RER based solar Photovoltaic (PV) systems and PEVs in a microgrid integrated with power grid. The paper also proposes a fault current limiter connected in parallel (anti-islanding protection) with the circuit breaker in the point of common coupling (PCC), thus providing current bypass circuit during abnormal conditions. The concept of the proposed scheme is validated under various operating conditions using a 24-hourly dynamic simulation. The results demonstrate the effectiveness of the proposed approach.**

Keywords- Microgrid; solar PV system; plug-in electric vehicles; power conditioning unit; power grid; anti-islanding protection

I. Introduction

The expansion of RER in power grids is expected to reach the maximum level in the near future, and the potential impact on the networks can be massive. It is commonly known that in the future, the locally available RER supported by energy storage devices, will integrate with the traditional generating technology to form a hybrid power grid. For improving the reliability of power grid, from economic point of view, it is preferable for these generating facilities to be interconnected with power grid. The use of Plug-in Electric Vehicle (PEV) in power grid as a source of power and a load as well is also another challenging problem, mainly due to the unpredictable nature of charging or discharging behavior, and uncertainty surrounds the controllability as Electric Vehicle (EV) is a very dynamic and may be plugged or unplugged at any instant [1, 2].

In recent years, the concept of microgrids in the urban and rural areas has drawn the interest of many researchers. The most interesting aspects are the integrations of RER and PEVs at the consumption sides to form the structure of incorporated microgrids towards smart grids, aiming to increase the reliability and efficiency of the power grid. However, the traditional power grids were designed long time ago, and currently these grids are not suited to coping with the penetration of RER or PEVs [2, 3].

In contrast to the RER, PEV is considered as a distributed load or energy storage, and thus, it is essential to identify the location of PEV available for charging or discharging, and the time of its connection to the grid. Therefore, control charging or discharging of PEV becomes an important strategy to mitigate the adversarial impacts on power grid [4]. Indeed, PEVs have potential amount of energy which can be utilized as spare energy storage for grid support (known as vehicle to grid "V2G") during peak load periods. PEVs can also be useful in a microgrid to provide backup energy storage when the RER have limited capacity, and hence, reducing the need of using local battery packs connected with the solar PV systems. Since the batteries in PEVs are regarded as mobile power storage devices with limited capacity constrained by travel requirements, a dynamic controllable technique is needed to insure an efficient use of the available energy storage capacity for microgrid support.

Several strategies have been proposed to control the generated power from RER and the stored energy in PEVs. For instance in [5], a control strategy has been proposed in a microgrid containing RER and PEVs. In this strategy, a current control is used for renewable energy generations during grid connected, while master-slave control utilized in the islanding mode. In the master-slave control, the energy storage is master whereas other renewable resources are slaves. A control approach was proposed in [6] to coordinate the maximum power point (MPP) of solar PV system with the battery storage control for providing voltage and frequency support in the islanded microgrid condition. The concept of integrated management has also been proposed in [7], while the effect of integrating PV systems with V2G is presented in [8]. An EV charging infrastructure using PV panels was examined to validate its benefits in reducing energy demand due to individual PEV charging [9]. A similar technique is also introduced in [10], here the PEV acts as a controllable spinning reserve but compared with the proposed approach in [9], solar PV was not introduced in [10]. For effective utilization of RER and improving the reliability in autonomous microgrid, a control method for energy storage systems has been proposed in [11]. The approach is based on the compensation and suppression of the frequency and power swing to maintain the stability in the islanding mode.

Usually, microgrid is connected to the medium side of power grid through the PCC. The RER and storage devices

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